A Magnetic LAr1-ND

(Work in progress)

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LAR1-ND Top View

Present concept

Measure Muon Through Range

TPC in Membrane Cryostat (LBNE design)

TPC: 2.3m deep
**5.7m wide**

Muon Spec: 1m deep
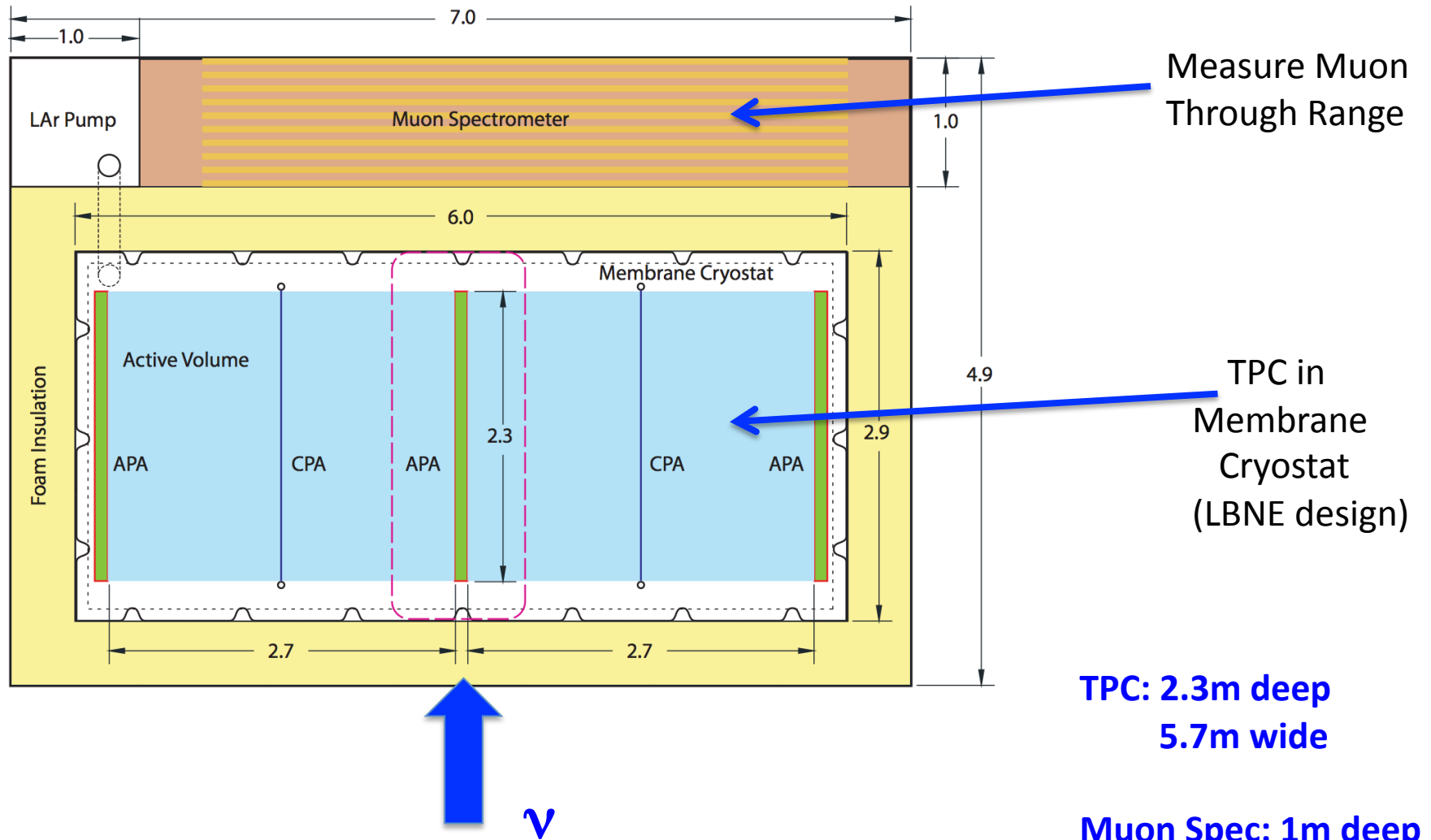
Principle

- Replace the Muon spectrometer by a coil around the TPC.
- Fill the whole available space with magnet + cryostat.

  Muon momentum measured by bending rather than range.

  – An iron return yoke.

  – Gain in TPC depth along beam.

  – Lose in TPC width because of coil and yoke

- Momentum of other particles can also be measured.

- Keep it simple: try a room temp. magnet instead of s/c one.

Would be the First experiment with a magnetic LAr TPC!
(Other than Tests)

NOTE: This is being considered as one option for the LBNE Near detector.
→ Could generate collaborators.
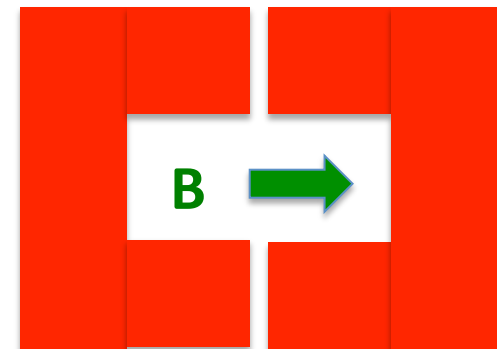
Based on the NOMAD concept

Magnet: UA1 → NOMAD→ T2K near det
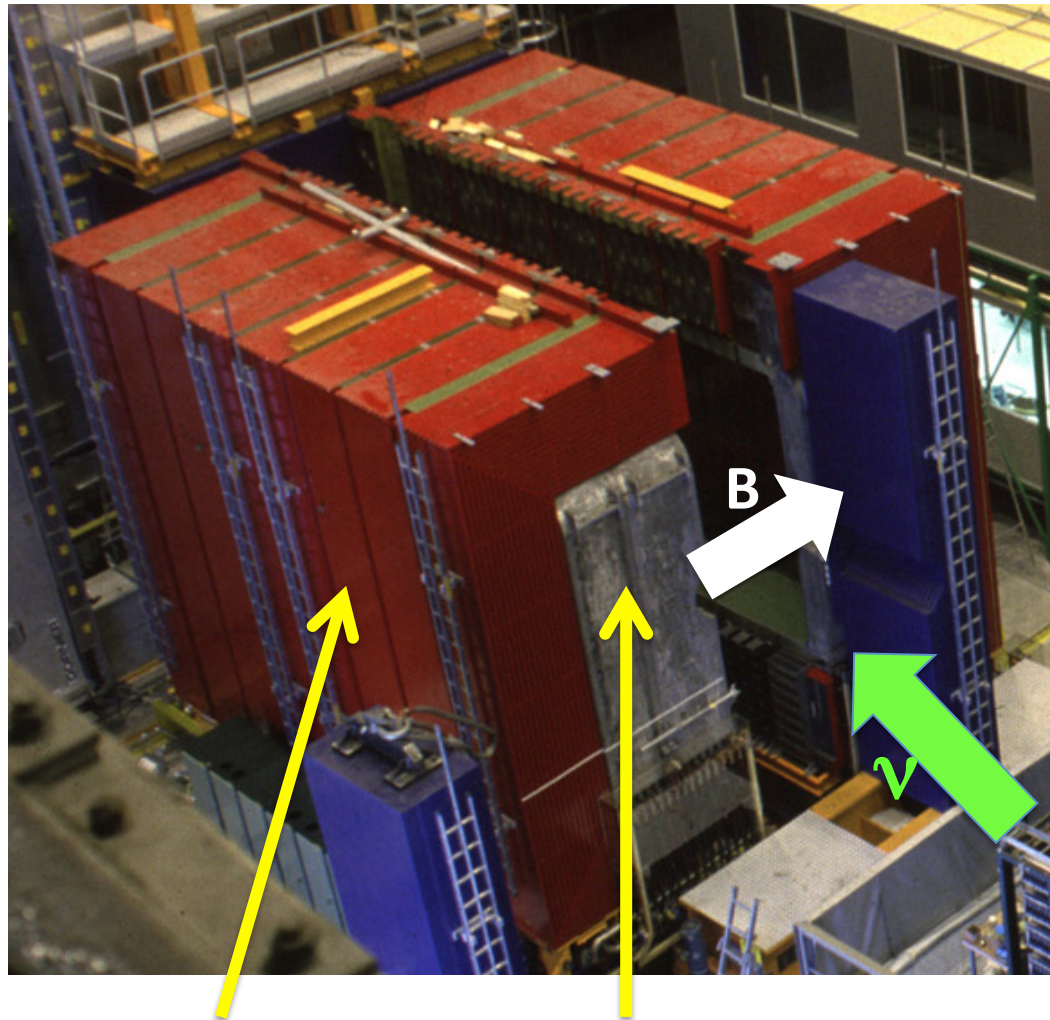
Built in 2 moveable halves

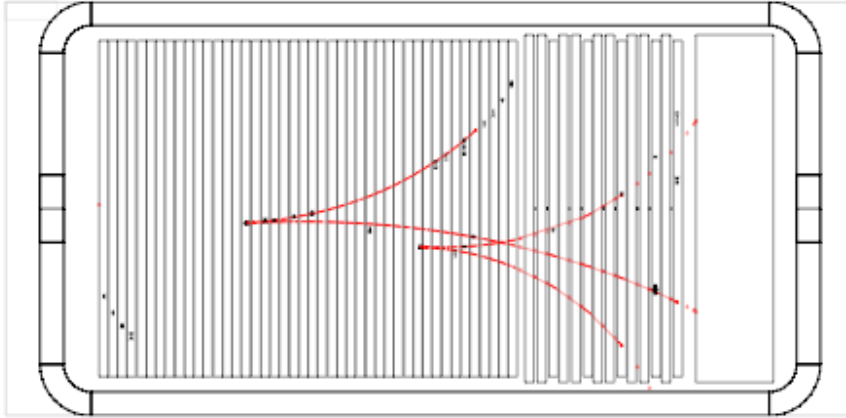**Horizontal field:**
Perpendicular to beam 0.5T
Uniform

End (ν) view

B

ν

B

Iron return yoke

Continuous coil
→ Solenoid

NOMAD →LAr1-ND

NOMAD		LAr1-ND
Field:	Horizontal (0.5T)	Vertical (0.5T?)
Dimensions:	7.0 x 3.6 x 3.1 m^3	Maximum :6.5 x 6.4 x 4.9 m^3
Detector Density:	0.1 $gm.cm^{-3}$	1.4 $gm.cm^{-3}$
Radiation Length:	~ 5m	0.14m
Detector mass:	2.7 tons	77 tons
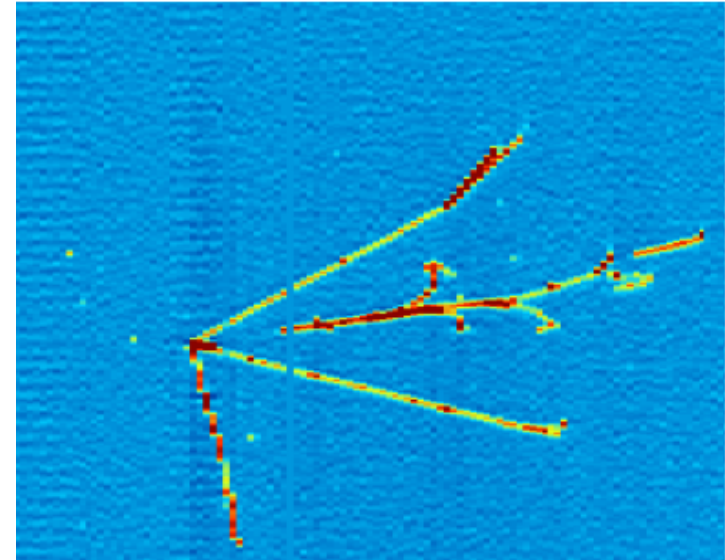
Top View

Side View

Coil

? Electronics?

Photon Detectors

B

6.5m
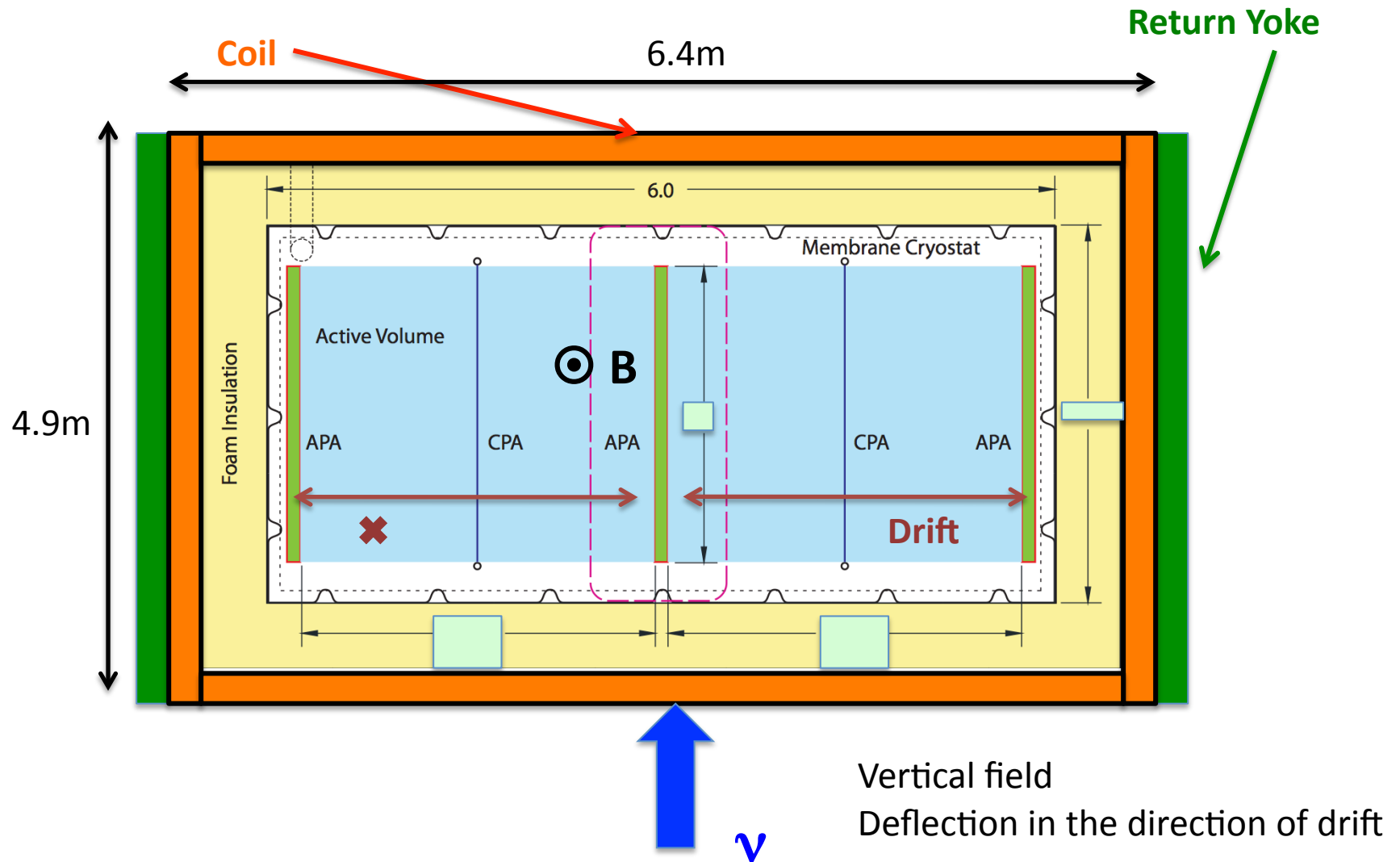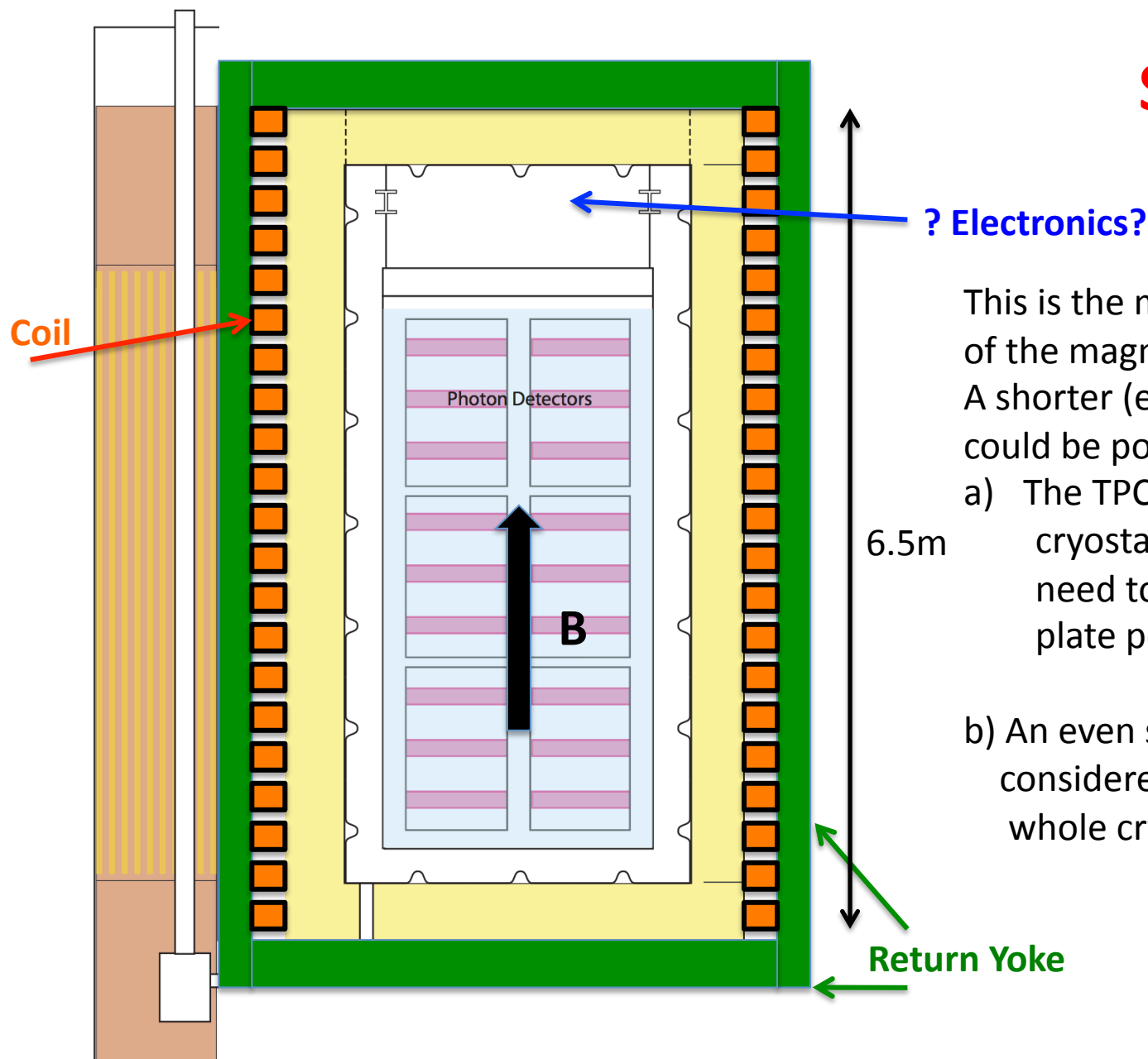
This is the maximum possible length of the magnet.
A shorter (easier, cheaper) version could be possible:
a) The TPC is shorter than the cryostat but we would need to figure out the TOP plate position.

b) An even shorter TPC is now being considered, reducing the whole cryostat

Return Yoke

Parameters: Resolution → B

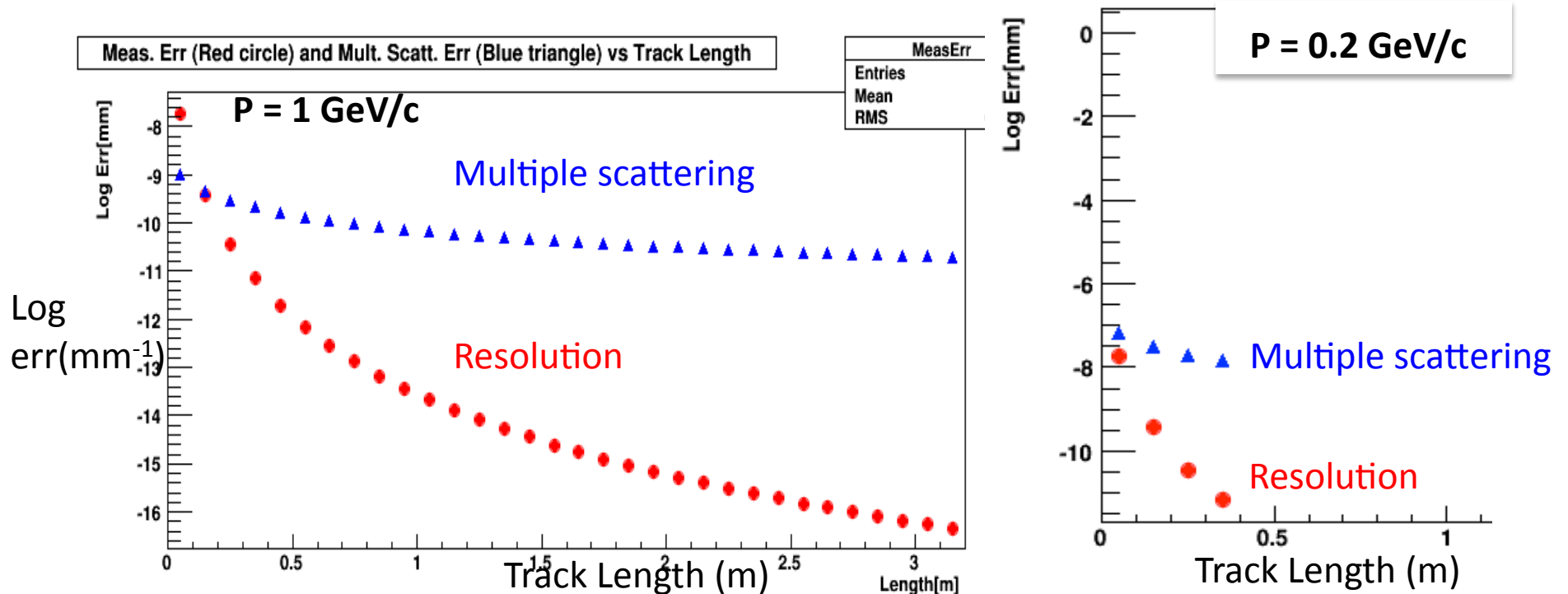- Along the beam direction drift is 1.6mm/microsec.

- 0.8mm per time tick at 2MHz. → 1mm resolution (ε) along drift per digitizing.

    (Better with fitting?)

- **Curvature:**

- $k = 1/R$ (bending radius) $= 0.3B/p$ B- Field (T), p = momentum

- **Errors in curvature:**

- Resolution:

- $dk(res) = (\varepsilon/L^2) \sqrt{[720/(N+4)]}$ L = Track length, N = # measurements

- Multiple scattering:

- $dk(ms) = (0.016(GeV/c)/Lp\beta) \sqrt{(L/X_0}$ X_0 = rad. Length (140mm)

- Overall: $dk = \sqrt{(dk(res)**2 + dk(ms)**2)}$

Resolution and Multiple scattering errors

Meas. Err (Red circle) and Mult. Scatt. Err (Blue triangle) vs Track Length

P = 1 GeV/c

P = 0.2 GeV/c

Multiple scattering

Resolution

Log err(mm⁻¹)

Track Length (m)

Track Length (m)

Multiple scattering errors dominate

Ignore Resolution errors: $k/dk = k/dk(ms) = [0.3B/p] \; / \; [(0.016(GeV/c)/Lp\beta) \; \sqrt{(L/X_0)}]$

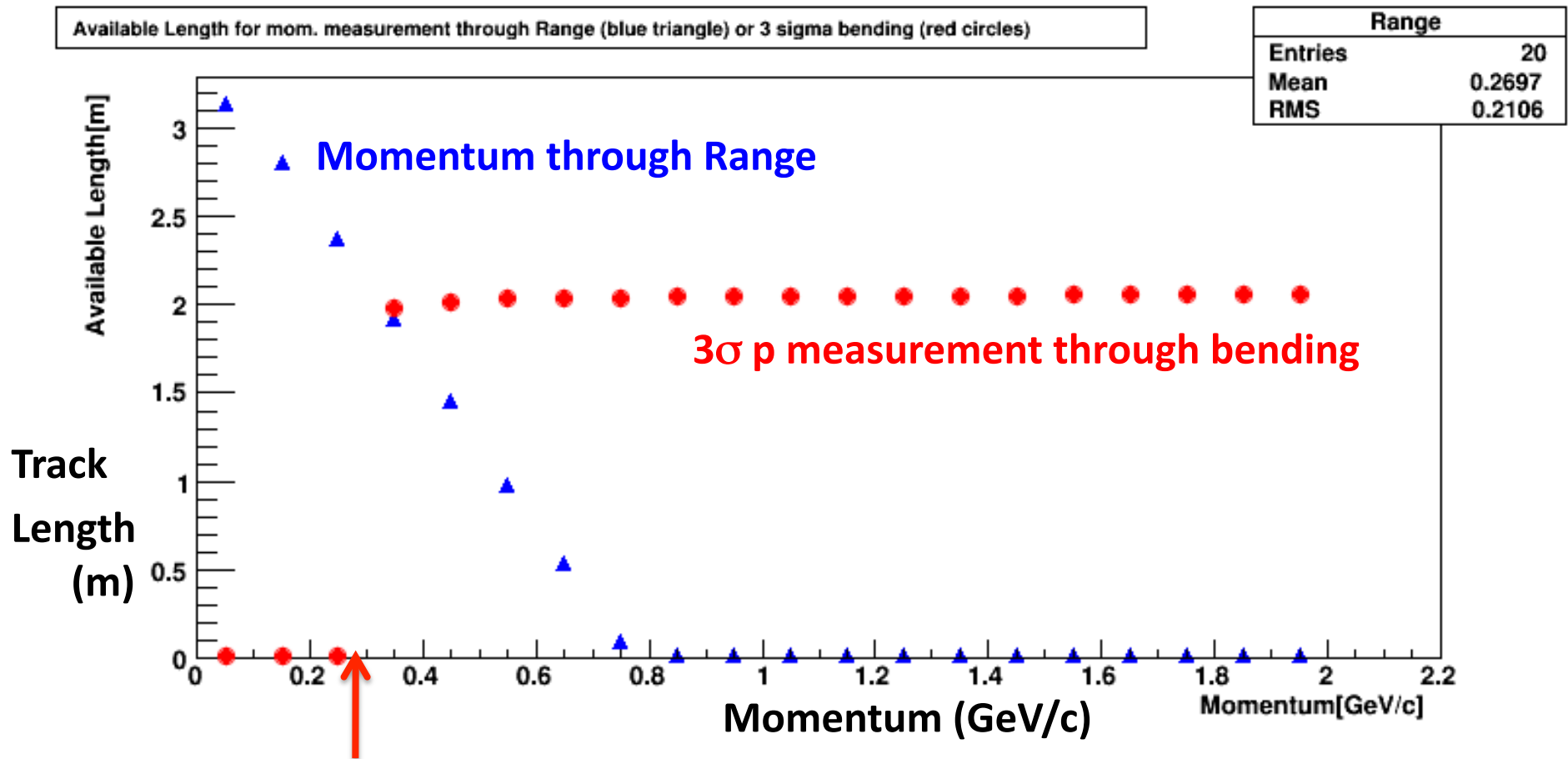$= [\; 0.3B \; L]/[0.016\sqrt{(L/X_0)}] \rightarrow$ For $\beta \sim 1.0$ Independent of p.

For $k/dk = 3 \; \sigma \rightarrow B = (0.16/L) \sqrt{(L/X_0)}$

To measure p at **3 σ** over 1m $\rightarrow$ **B = 0.43T.**

Track Length over which p can be measured

For a 3.2m long TPC, B=0.5T

Available Length for mom. measurement through Range (blue triangle) or 3 sigma bending (red circles)

Range	
Entries	20
Mean	0.2697
RMS	0.2106

Momentum through Range

3σ p measurement through bending

Track Length (m)

Available Length[m]

Momentum (GeV/c)

Momentum[GeV/c]

- Below ~ 0.3 GeV/c: range < 1m → Cannot measure p at 3 σ.
- But can measure through range over a significant portion of TPC.

Charge measurement:

For a 3.2m long TPC, B=0.43T

- We have a 2.7×10^{-3} probability of the momentum being outside of 3σ.
- But only a 1.35×10^{-3} probability of getting the charge wrong.

- If we were satisfied with a probability of getting the charge wrong of **2.2%**, (one sided 2σ) we would only need to measure the momentum over **0.68m** instead of 1m.

Depends on the physics.

How thick a Return yoke?

- 0.42T Flux coming out of the coil over 5.5m will have to be channeled through a thickness of iron t at the top, bottom and sides.

- Assuming that iron saturates at **1.8T**, 1.8 x t = 0.42 x 5.5 → **t= 1.3m.**

- Iron return on either side of the coil, they each need to be 0.65m thick.
   Same for Top and Bottom iron slabs.

- Adding a ~20cm coil, we lose 2 x (0.20+0.65) = **1.7m.**

- TPC would go from 5.4m to **3.7m width**.

- In depth we would gain: Spectrometer – 2 x coil thickness = 1.0 - 0.4 = **0.6m.**

- So TPC's depth would go from 2.3m to 2.9m.

- TPC overall volume change (3.7x2.9)/(5.4 x 2.3m)=**0.86.**

- **14% loss** would be in a less dense ν flux than
    TPC gain area. → Less effective loss.

- The Top slab would be removable for access to the TPC.

- The Bottom slab could replace part of the
   concrete support.

entry.vtxy:entry.vtxx

From Georgia
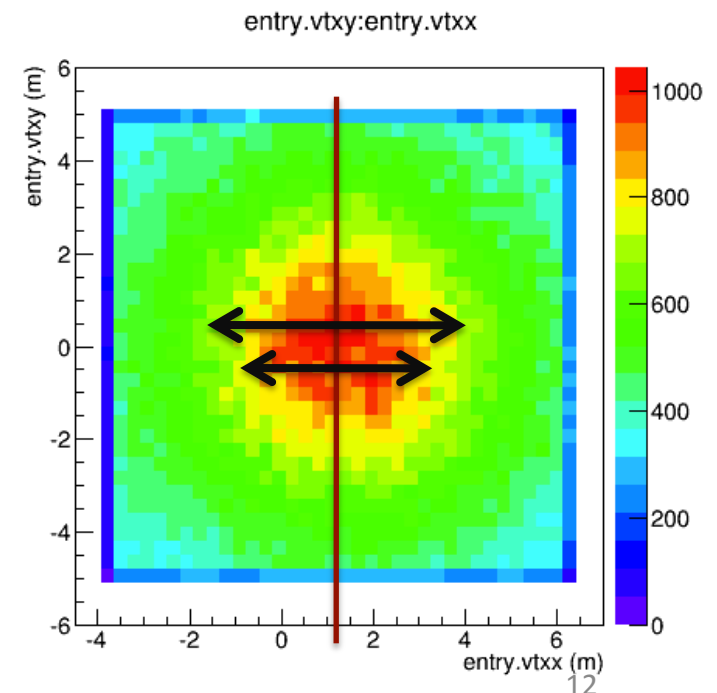
Top View
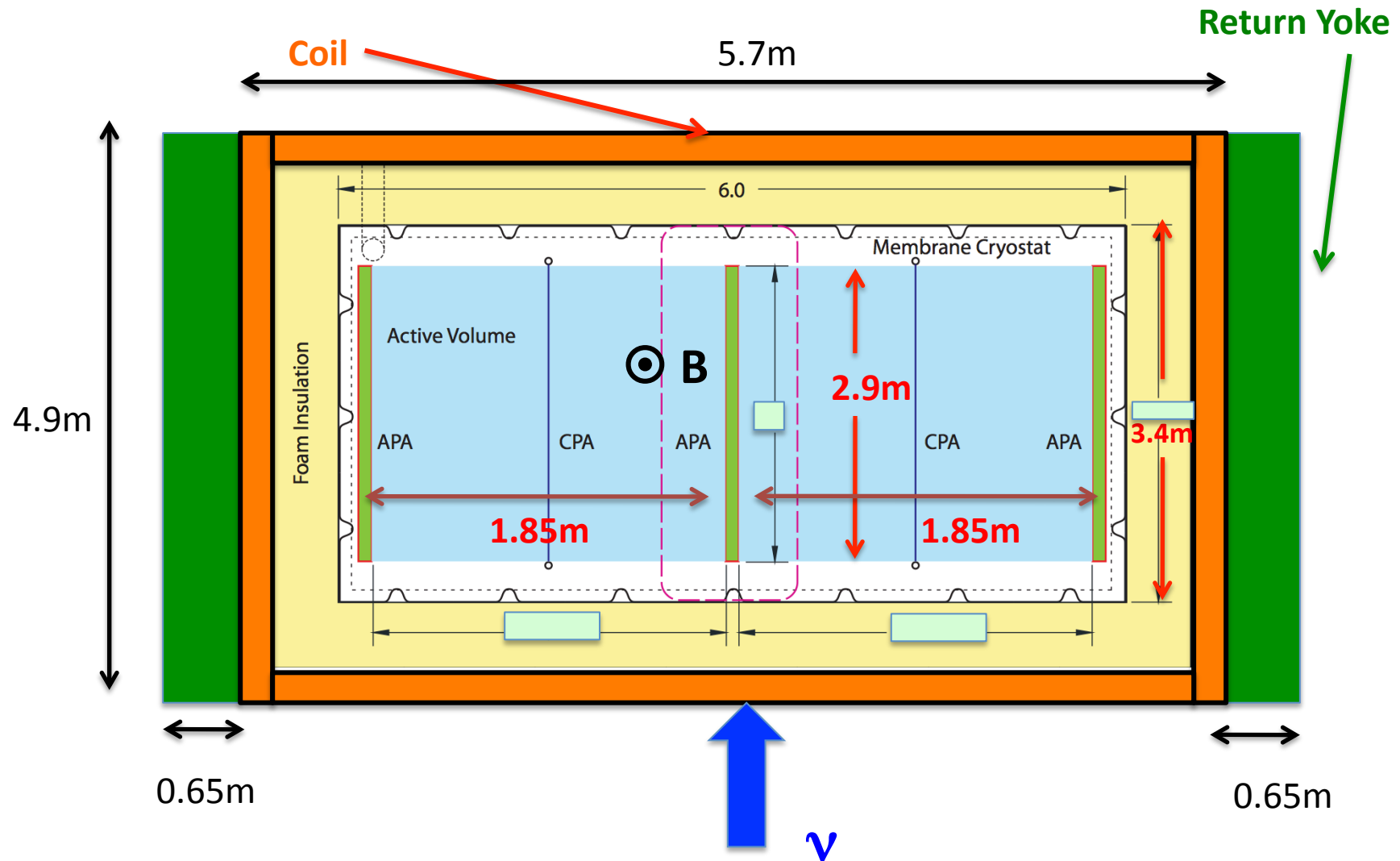
Current/turns to produce B=0.42T

- B (0,0) = centre of solenoid

- Length = L = 6.5m

- Radius = R   Rectangular ~ 6.4m x 4.9 m $\rightarrow$ πR^2 $\rightarrow$ R(effective) ~ 3.2m

- Number of turns/m = n = 40/m

- Current = I = 3200 A

- $0.42T = B = \mu_0 nI \; L/ \sqrt{(L^2 + 4R^2)} = (4\pi \times 10^{-7})\, nI \times 6.5/\sqrt{(6.5^2+4\times3.2^2)}$

- $(4\pi \times 10^{-7})\, 40 \times 3200 \times 6.5/\sqrt{(6.5^2+4\times3.2^2)}$

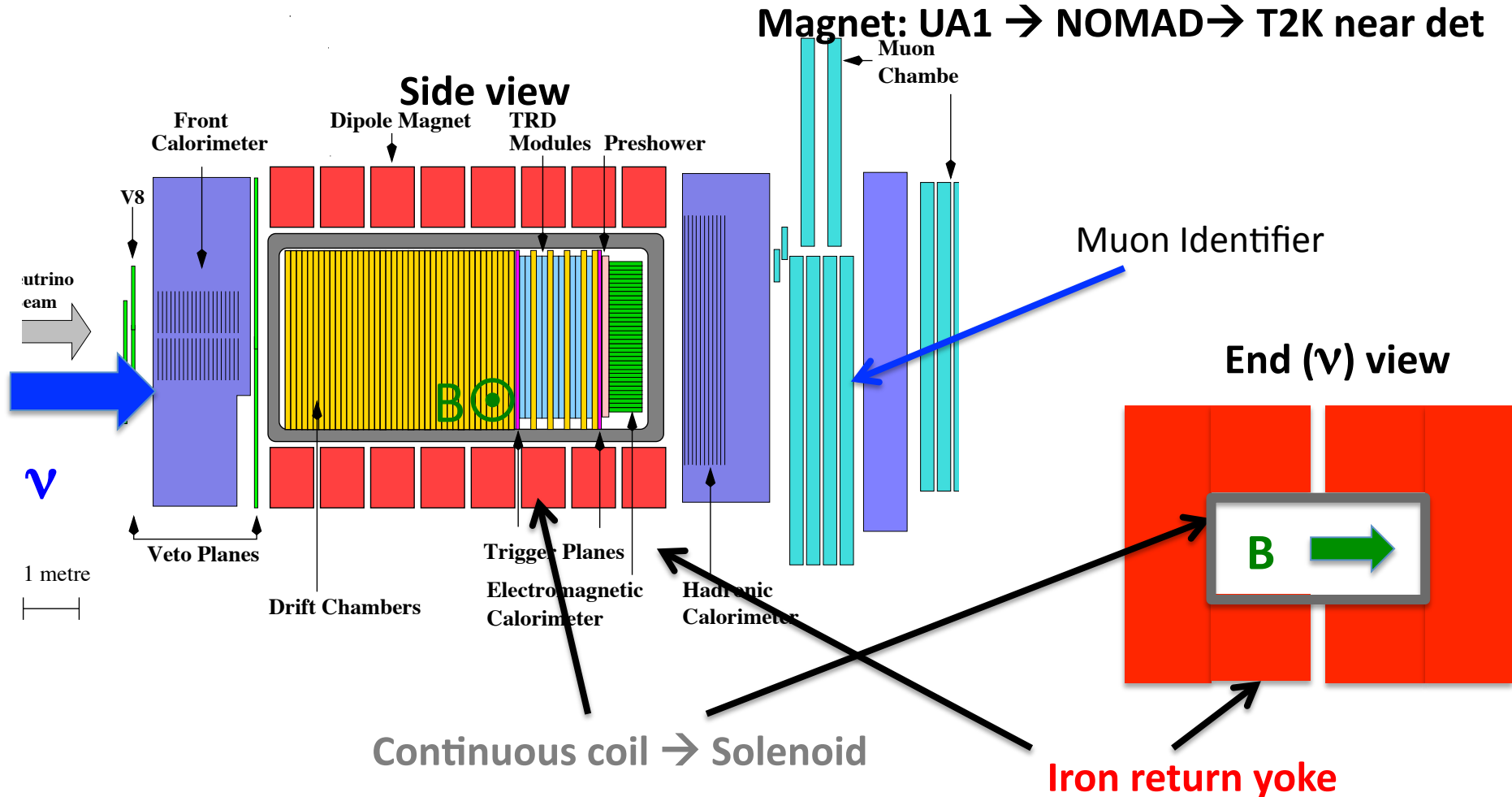 $nI = 4.7 \times 10^5$ amps.turns/m   ~ 4700A x 100turns/m

Problems

- Cost? Needs to be worked out.→ Engineering.
    (Note that we save on spectrometer….)
- Time scale?
- Power supply?
- Demineralized water? Any water in SciBooNE enclosure?
- Does it compromise any physics? (Curling tracks, widening of showers, ….).
- Does it compromise any of the cryogenics, electronics, …?
- Can we reduce the height (length) of the magnet?
- How does it fit with the foam insulation?

- Have been in close contact with Bruce.
- Bruce has been in contact with Craig and Jim Kilmer.
    → Existing magnets? Existing iron?

Back up

Based on the NOMAD concept

Magnet: UA1 → NOMAD→ T2K near det

Side view

Front Calorimeter

Dipole Magnet

TRD Modules Preshower

Muon Chambe

V8

eutrino eam

ν

B⊙

Muon Identifier

End (ν) view

B →

Veto Planes

Trigger Planes

Electromagnetic Calorimeter

Hadronic Calorimeter

Iron return yoke

1 metre

Drift Chambers

Continuous coil → Solenoid

Horizontal field: Perpendicular to beam 0.5T

Parameters: Power

- How much power would it require?
- NOMAD used up 5MW.
- This will be a bigger magnet.
- Ohmic resistance: NOMAD had 0.0576 ohms for
  - a) Length of 7.0m compared to 6.5m here. $\rightarrow$ about the same
  - b) Circumference of 3.6 x 3.08 compared to 4.9 x 6.4 $\rightarrow$ x 31/(11) = 2.8
- Ohmic resistance = 0.0576 x 2.8 = 0.16 ohms.
- Power: 5MW x 2.8 = 14MW. Assuming same current.
- NOMAD coil: 5.4 x 5.4 cm^2 Al bars with a 2.3cm channel for cooling.
- Making the coil out of Copper reduces the resistance by:
   1.68×10^{-8} Ω.m/2.82×10^{-8} Ω.m = 0.596 $\rightarrow$ 8 MW.
- Water (demineralized) flow: 15 liters/sec for 0.6MW x 1.6 for 1.0 MW?